National Renewable Energy Laboratory

Distributed Power Interconnection

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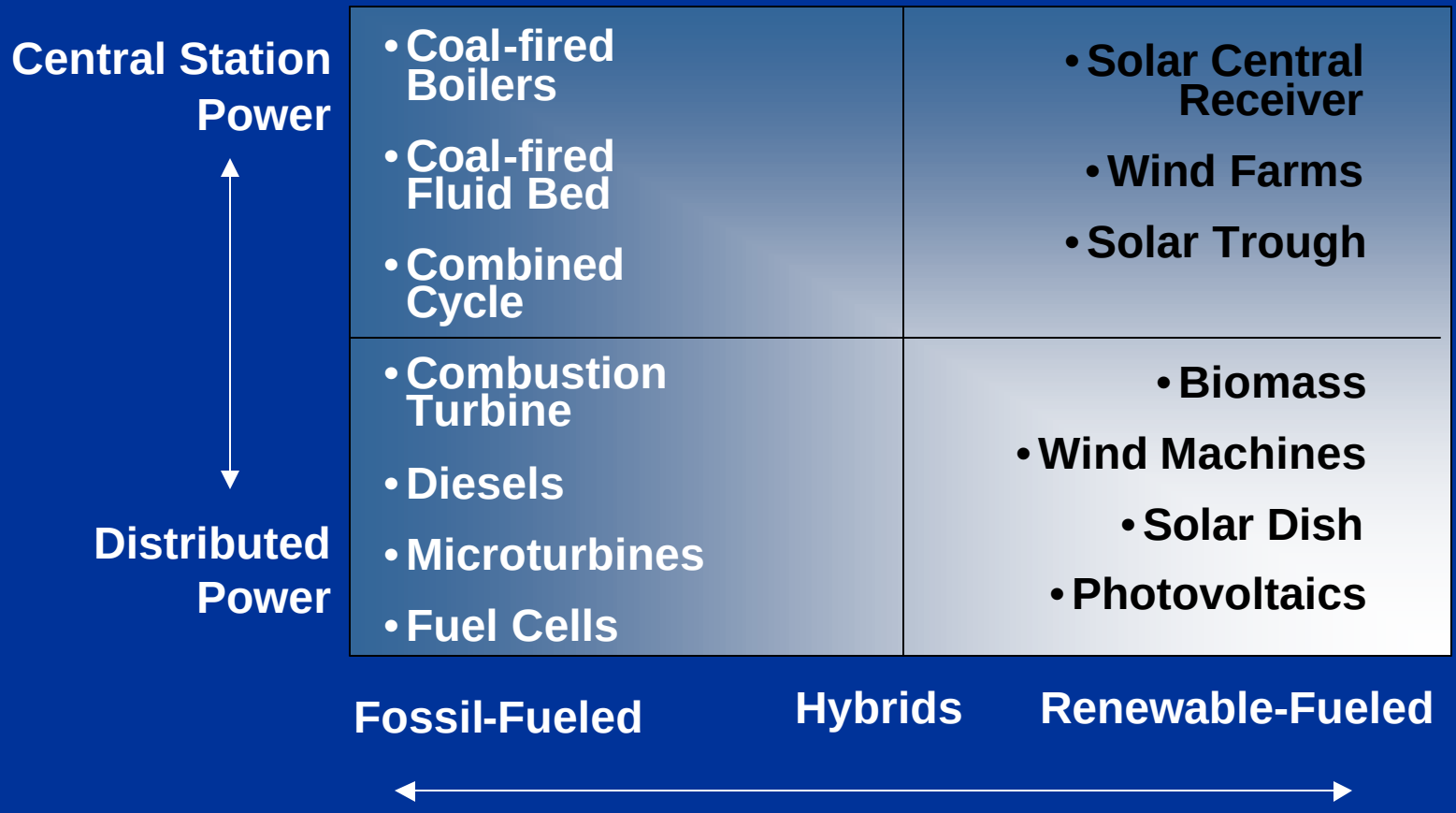
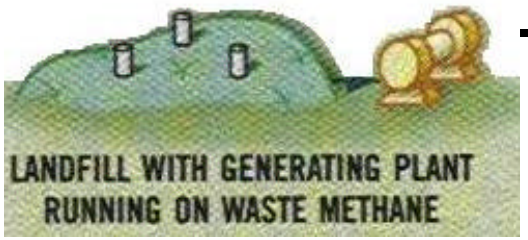
Examples of Distributed Power

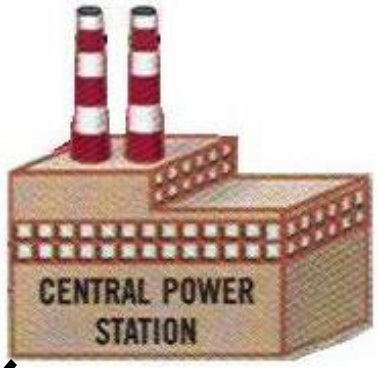
- **Some representative prime mover candidates:**
  - **internal combustion engines**
  - **combustion turbines and microturbines**
  - **Stirling engines**
  - **fuel cells**
  - **photovoltaic solar panels**
  - **small wind turbines**
  - **small biomass power**
- **They use fuels delivered:**
  - **in bulk, e.g., diesel, propane, biomass**
  - **in pipelines, e.g., natural gas**
  - **by nature, e.g., sunshine and wind.**

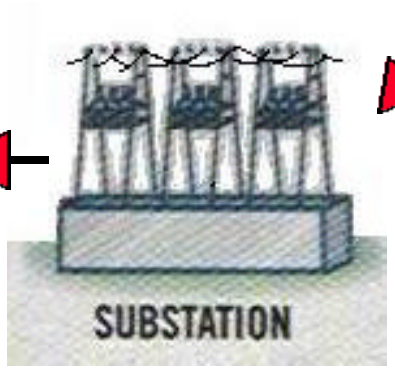
Domains of Renewable and Renewable/Fossil Hybrid Distributed Power Systems



Future Electrical Generation





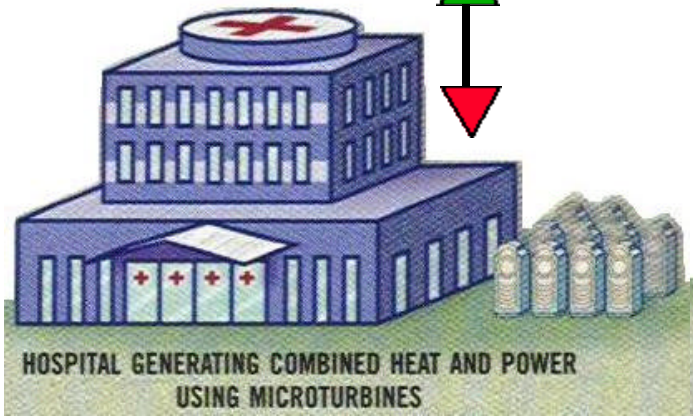


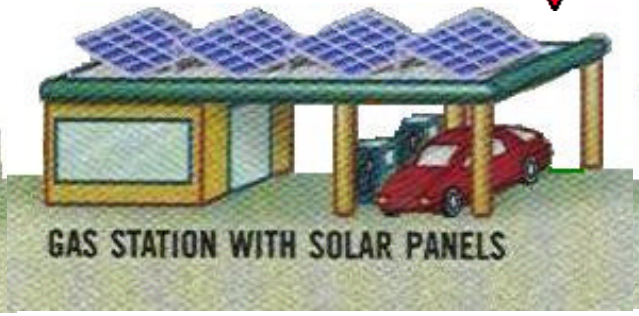
RED Arrows:

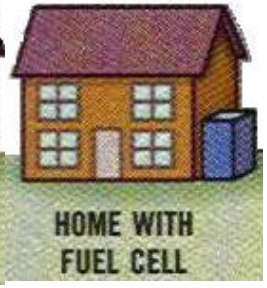
Power sold by central generators to homes and commercial buildings

Green Arrows:

Power flowing from buildings back to substations







Distributed Power Benefits

- Modular and short manufacturing/installation cycle time
- Grid independent or grid connected
  - minimize transmission constraints and losses
- Greater reliability and power quality
- High system efficiency with waste heat utilization (CHP)
- Reduced emmissions with clean energy conversion systems
- Hybrid renewable/gas /hydrogen systems

Distributed Power Opportunities

- High value situations: reliability, power quality, grid independence
- Ancillary services: voltage support/stability, VARs, contingency reserves, ...
- Combined heating, cooling, and power systems - reduced costs
- Power park: industrial/commercial
- Enhanced remote & village power

Interconnection
System Integration and Aggregation

- Vast Operational System
- 6000 to 7,000 Generators
- 50,000 to 140,000 Transmission Lines
- 40,000 to 100,000 Substations
- 130,000,000 End-User Customers
- Timing and Time Scales
- Days to Start Plants to Fractions of Seconds in Automated Responses
- Human Factors and Education
- Behavior

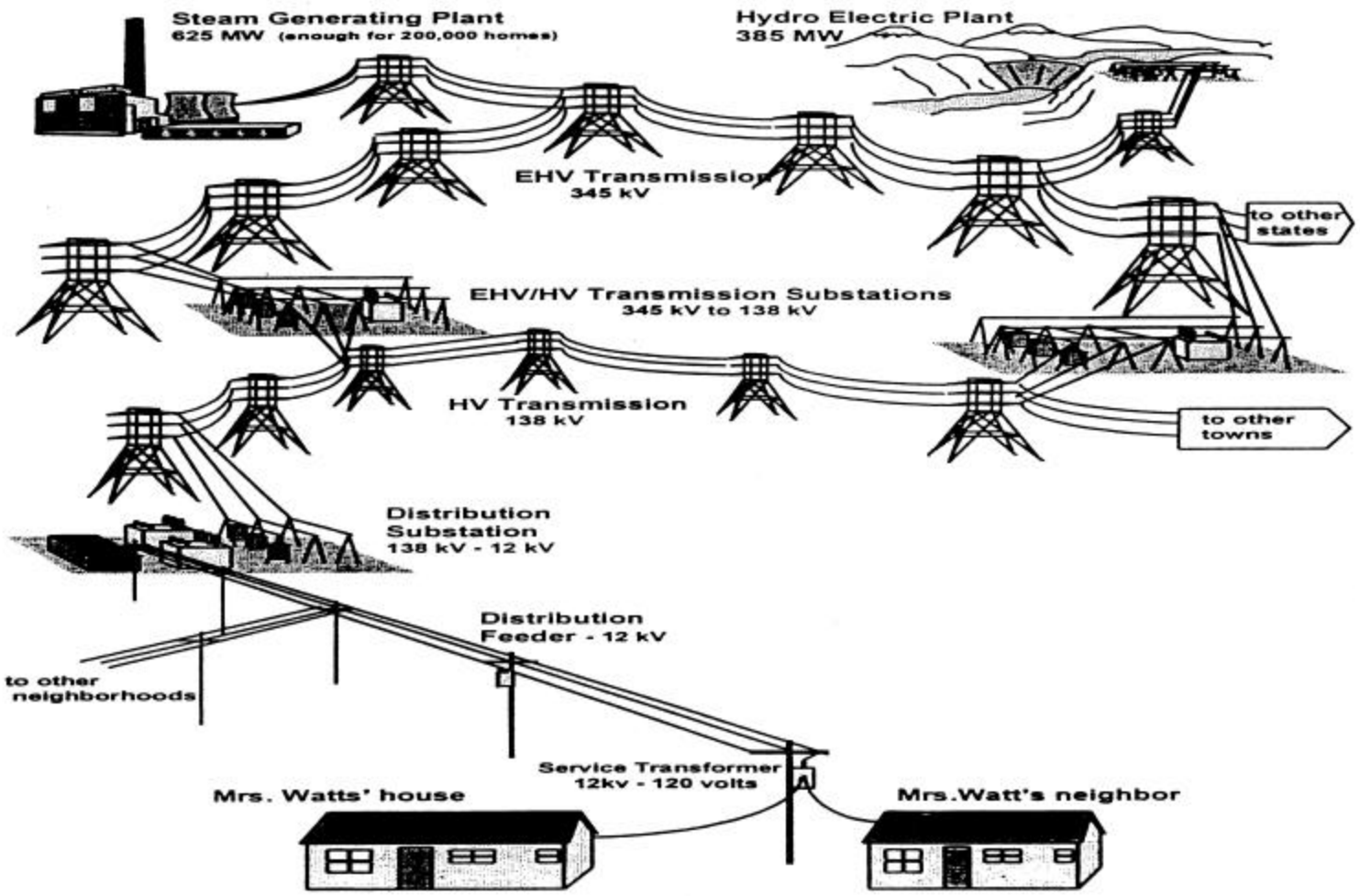


Figure 7.8 A power system consists of several levels: generation, extra high voltage (EHV) transmission, high voltage (HV) transmission, distribution, and utilization.

Source: *Understanding Electric Utilities and De-Regulation*; L. Philipson and H.L. Willis, 1999

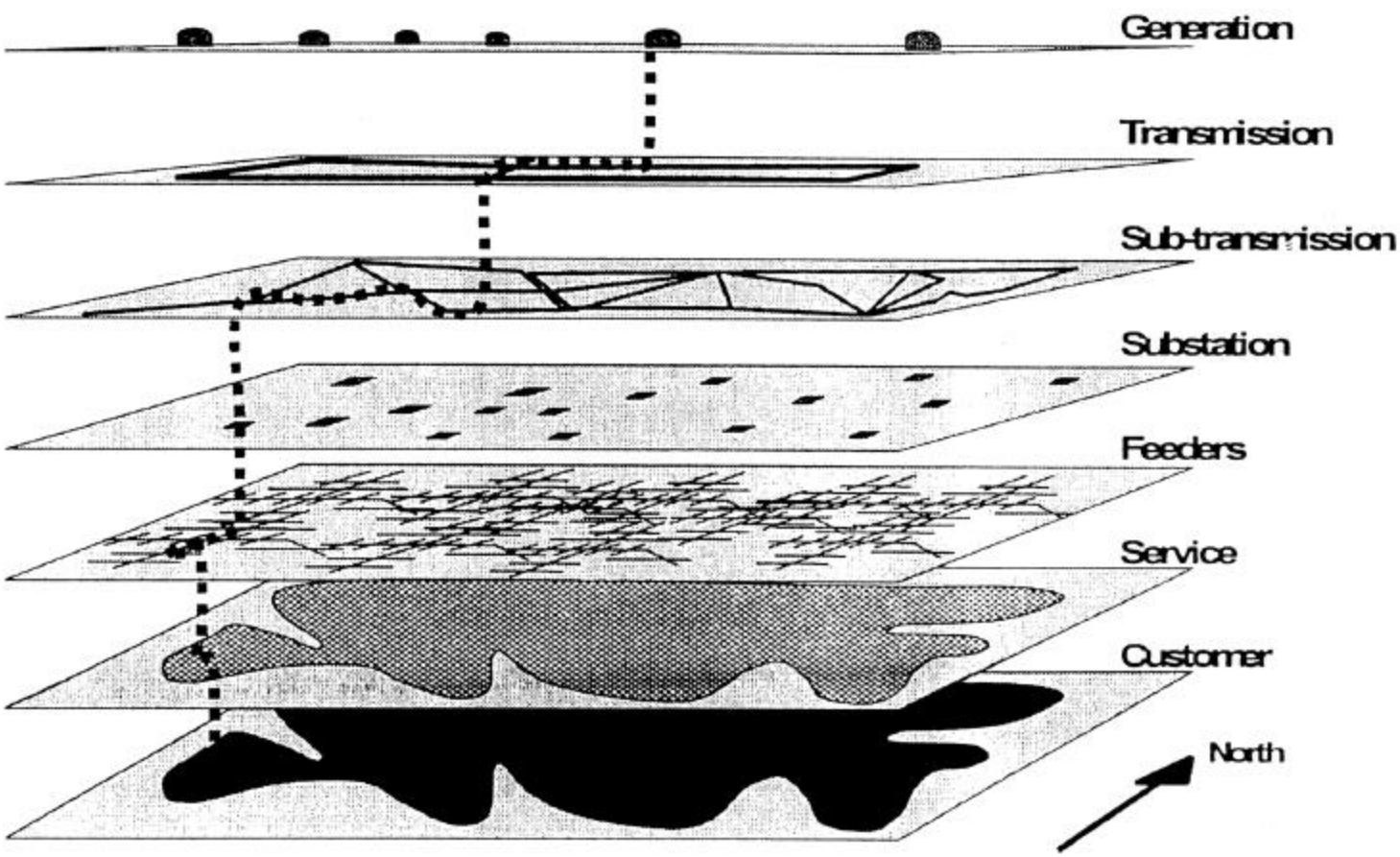
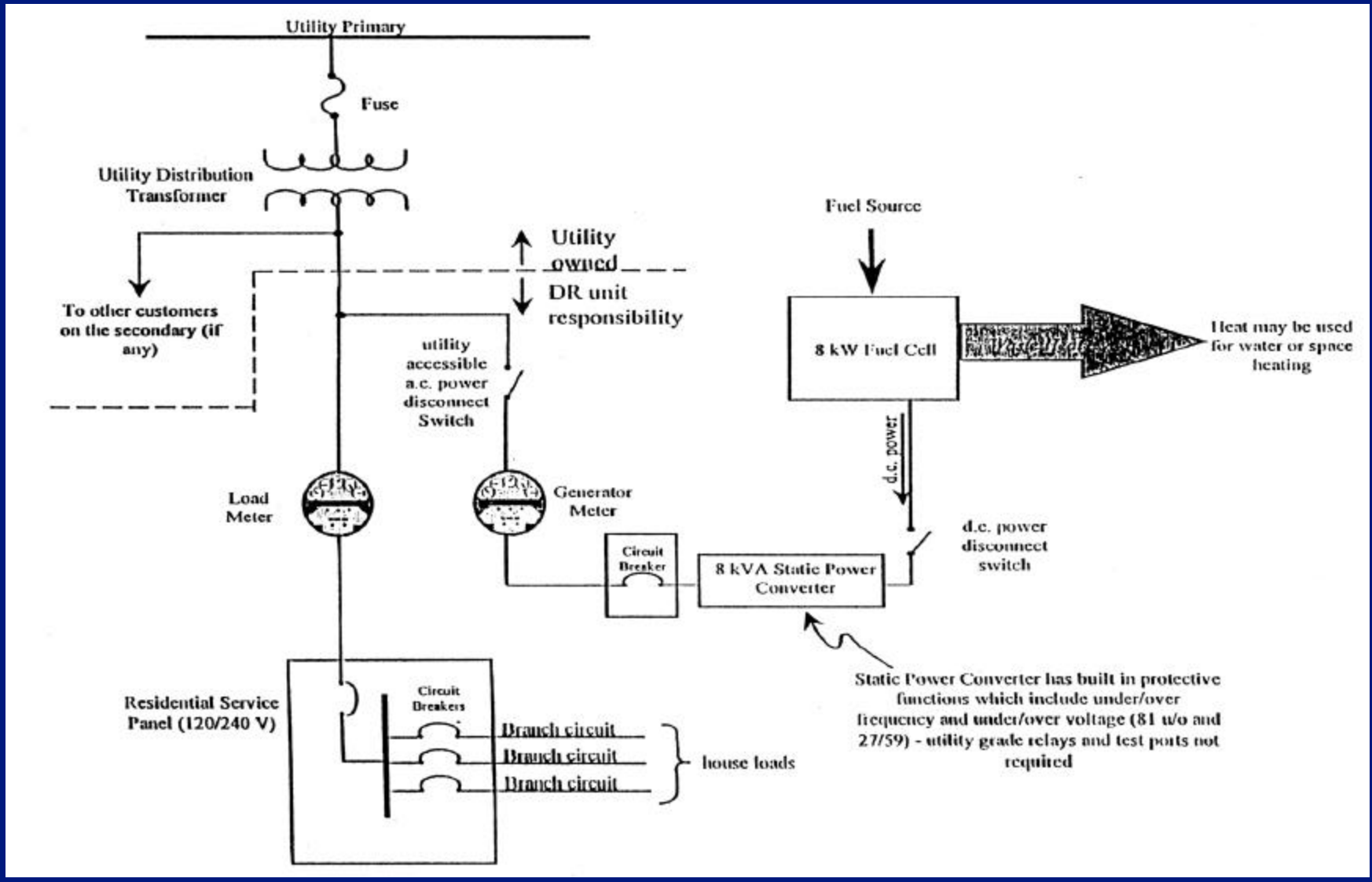
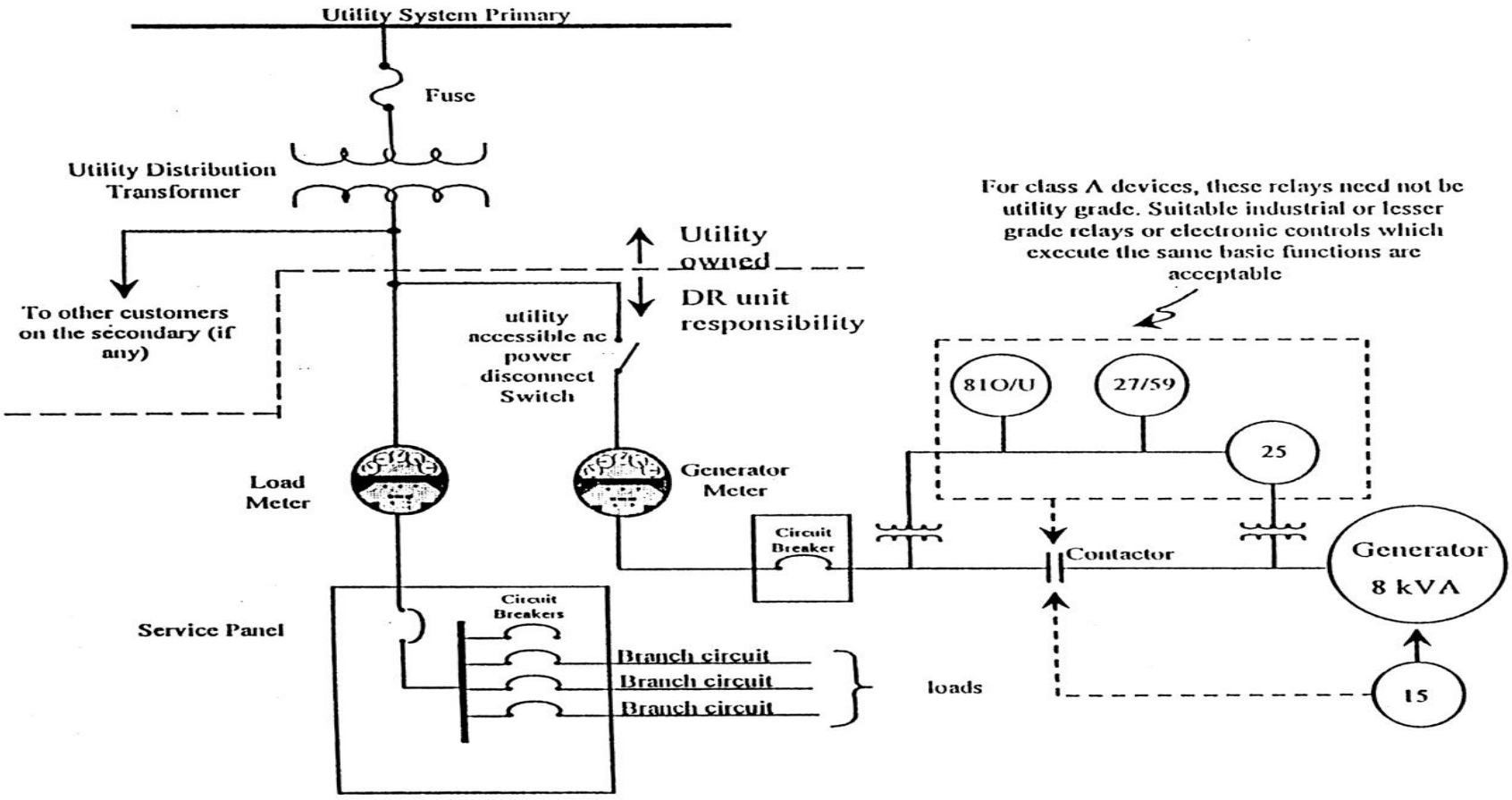


Figure 7.9 A power system is composed of service layers, each performing its function over the entire service area. Power flows down from the top (generation) to the bottom (customer) layers. Power follows a route through all layers on its way to any customer (dotted line).

Source: *Understanding Electric Utilities and De-Regulation*; L. Philipson and H.L. Willis, 1999


Utility Primary
Fuse
Utility Distribution Transformer
To other customers on the secondary (if any)
Utility owned
DR unit responsibility
utility accessible a.c. power disconnect Switch
Load Meter
Generator Meter
Circuit Breaker
8 kVA Static Power Converter
Fuel Source
8 kW Fuel Cell
Heat may be used for water or space heating
d.c. power
d.c. power disconnect switch
Static Power Converter has built in protective functions which include under/over frequency and under/over voltage (81 u/o and 27/59) - utility grade relays and test ports not required
Residential Service Panel (120/240 V)
Circuit Breakers
Branch circuit
Branch circuit
Branch circuit
house loads

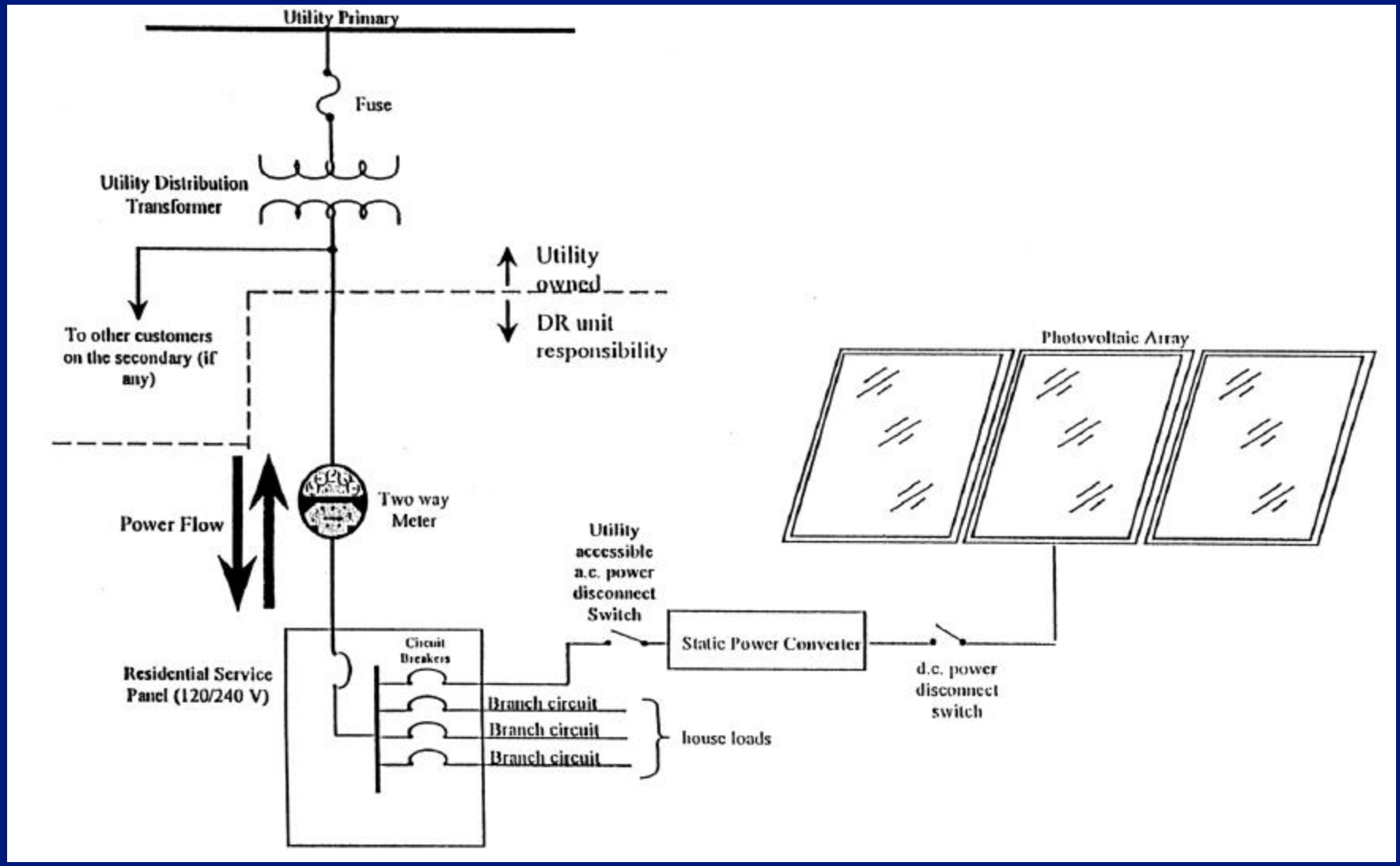


Notes: 81O/U = Under/over- frequency relays

27/59 = Under/over- voltage relays

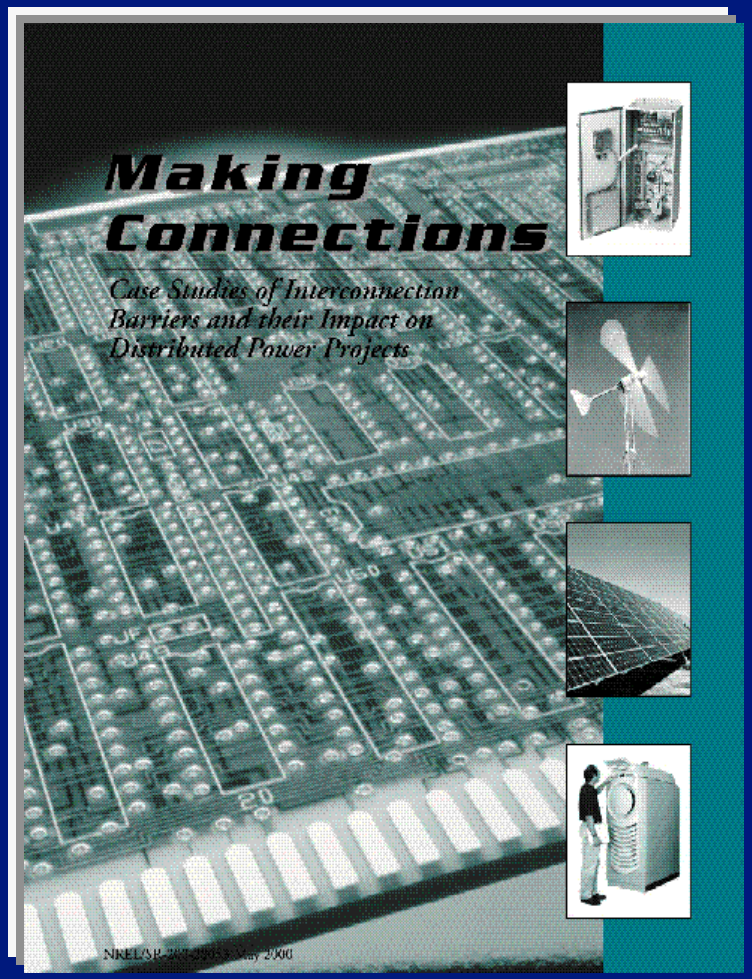
25 = Synchronizing relay (not required for induction generator)

15 = Speed matching relay (Ind. generator).


Utility Primary
Fuse
Utility Distribution Transformer
Utility owned
DR unit responsibility
To other customers on the secondary (if any)
Photovoltaic Array
Power Flow
Two way Meter
Utility accessible a.c. power disconnect Switch
Static Power Converter
d.c. power disconnect switch
Residential Service Panel (120/240 V)
Circuit Breakers
Branch circuit
Branch circuit
Branch circuit
house loads

Interconnection Barriers

"Making Connections" Report



- Released May 1, 2000
- Financed and published by DOE/NREL, with support from
- 90 DG projects were identified, 65 surveyed, 26 summarized and included in report
- Projects ranged from 0.3 kW (PV) to 26 MW (gas turbine)
- Available on the Web as PDF file at the following address: http://www.eren.doe.gov/distributedpower/barriersreport/

Making Connections - Ten-Point Action Plan

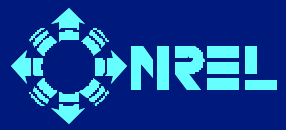
- Reduce Technical Barriers
  - Adopt uniform technical standard for interconnecting distributed power to the grid
  - Adopt testing and pre-certification procedures for DG equipment
  - Accelerate development of distributed power control technology and systems
- Reduce Business Practice Barriers
  - Adopt standard commercial practices for any required utility review of interconnection
  - Establish standard business terms for interconnection agreements
  - Develop tools for utilities to assess the value and impact of distributed power at any point on the grid

Making Connections - Ten-Point Action Plan

- Reduce Regulatory Barriers
  - Develop new regulatory principles compatible with distributed power choices in both competitive and utility markets
  - Adopt regulatory tariffs and utility incentives to fit the new distributed power model
  - Establish expedited dispute resolution processes for distributed generation project proposals
  - Define the conditions necessary for a right to interconnect

Mitigation of Interconnection Barriers

- **Technical requirements for grid interconnection**, e.g., safety and power quality
- **Permitting**, e.g., environmental, building codes, etc.
- **Rules of engagement** for interconnection, e.g., legal, economic, financial and regulatory
- **Obtaining "full value"** for benefits of the distributed power installation.



IEEE (Institute of Electrical and Electronics Engineers)

Interconnection Standard (P1547)

IEEE Interconnection Standard P1547

- **Title:** ***Standard for Interconnecting Distributed Resources with Electric Power Systems***
- **Scope:** This standard establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS).
- **Purpose:** Provide a uniform standard for interconnection of distributed resources with electric power systems, and requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.
- **Sponsor:** IEEE SCC21 -- *Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage*; Chair, R. DeBlasio.

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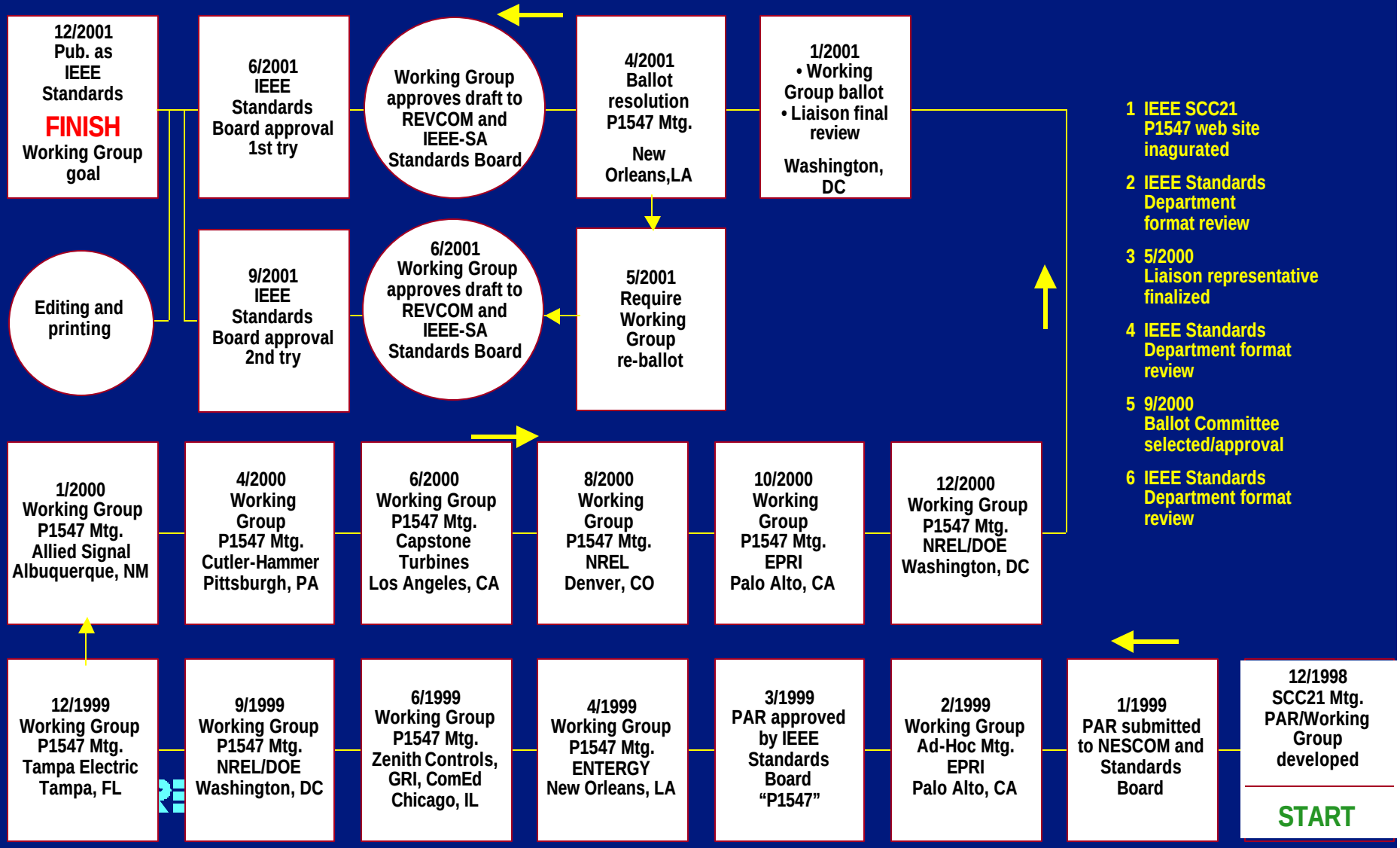
P1547 Development Approach

- Voluntary consensus standard
  - Hallmark of the standards process
  - Open to all dedicated parties
  - IEEE ballot member categories:
  - - General Interest, Producer, User
- Fast-track schedule
  - April 1999 -- IEEE approved P1547 project
  - March 2001 -- Complete ballot action
  - => On target for year 2001 IEEE publication

Proposed Timeline for P1547



IEEE P1547 Development Status

- Ballot of Draft 7: Feb. 27 - Mar. 28, 2001
  - Draft 7: 25 pages of criteria, requirements, and information
  - 167 Ballot members
- P1547 Working Group (WG) at 350 members
- P1547 WG organization
  - R. DeBlasio (NREL) -- Chair J. Koepfinger (Duquesne) -- Vice Chair
  - F. Goodman (EPRI) -- Vice Chair T. Basso (NREL) -- Secretary
- Meetings every 2 months (started Dec. 1998)
- Last P1547 WG Meeting April 18 - 20, 2001
  - Draft 7 ballot results
  - Prospective new IEEE DR project activities
- Next Meeting October 15-19, 2001, (Re-circulation/Resolution)
- P1547 Web site http://grouper.ieee.org/groups/scc21/1547

IEEE P1547/D07 Contents

- INTRODUCTION
- 1.0 OVERVIEW
- 2.0 REFERENCES
- 3.0 DEFINITIONS
- 4.0 INTERCONNECTION TECHNICAL
- SPECIFICATIONS AND REQUIREMENTS
- 5.0 TEST SPECIFICATIONS AND REQUIREMENTS
- Annexes (Informative)
- ANNEX A -- INTERCONNECTION TEST FOR RESPONSE
- TO ABNORMAL CONDITIONS
- ANNEX B -- COMMISSIONING TEST VIA SETTINGS ADJUSTMENT
- ANNEX C -- BIBLIOGRAPHY

IEEE P1547 NATIONAL DEBATE CONTINUES NATIONAL INTERCONNECTION STANDARD STATUS

- BALLOT ACTION COMPLETED APRIL 1, 2001
- 91% BALLOT RETURNS (167 BALLOTING MEMBERS)
- MET THE IEEE 75% RETURN REQUIREMENTS
- ACHIEVED 66% AFFIRMATIVE (NEED 75%)
- RESOLUTION OF BALLOTS UNDERWAY
- RECIRCULATION OF DRAFT 7 PLANNED TO ACHIEVE 75% OR GREATER AFFIRMATIVES

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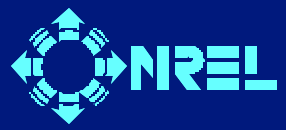
Summary of IEEE P1547/D07 Eligible Voters by Interest Category (4/20/01)					
Interest Category	Affirmatives	Negatives	Abstentions	Not Returned	Total
User	31	23	2	4	60
Producer	37	12	2	3	54
General Interest	28	15	0	5	48
Government - Academic - Consultant	2	0	1	2	5
Voting Tally	98	50	5	14	167
Abstention details: 5 = 3 for lack of time and 2 for lack of expertise					



SOME KEY ISSUES

- MINIMUM VS MAXIMUM REQUIREMENTS
- FIELD TESTING VS TYPE TESTING
- SECONDARY GRID AND SPOT NETWORKS
- GRID/DG MONITORING AND CONTROL
- VOLTAGE REGULATION/STABILITY
- DG PENETRATION/AGGREGATION

Prospective New IEEE DR Activities

DR unit

Interconnection System

- P1547 Draft Std for Interconnection of DR with EPS
- NEW: Interconnection System Testing (P1589)
- NEW: Guidelines for Communication-Control of DR
- NEW: Guidelines for Certification of DR equipment
- NEW: Application Guide for DR

Area EPS

- NEW: Guidelines for Network Specifications & Applications with DR
- NEW: Recommended Practice for Distributed Generators and Equipment-Specifications and Performance

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Summary - Key Points to Interconnection Success

1. Systems Integration - Develop and advance semi-autonomous and autonomous systems interconnection technology for universal application that is compatible, safe, cost effective, and meets the requirements of IEEE P1547 for system interconnection (integration and aggregation) of distributed power systems with the electric power system.

2. Mitigation of Regulatory and Institutional Barriers – Work with local, state, and industry organizations to reduce barriers to deployment of distributed power resources that will not compromise consumer protection,environmental values, and health and safety considerations.

IEEE P1547 Interconnection Definitions

1. Distributed Resource (DR) – sources of electric power that are not directly connected to a bulk power transmission system
2. Electric Power System (EPS) – facilities that deliver power to a load
3. Interconnection – the result of the process of adding a DR unit to an area EPS
4. Interconnection Equipment – individual or multiple devices used in an interconnection system
5. Interconnection System – the collection of all interconnection equipment, taken as a group, used to interconnect a DR unit(s) to an area EPS